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Analysis of photographic problems in Project X

The vehicle will operate at ~~85,000~~ 70,000 feet and travel at ~~600~~ 500 mph. It may stay aloft about 8 hours.

We have arbitrarily selected an objective of obtaining maximum quality photographs from sunrise to sunset for latitude 40° N to 70° N at all seasons of the year during which the sun rises above the horizon. Under these conditions it is believed that, on the average, the minimum scene luminance measured from the camera position will cover the range 50 to 1200 foot lamberts. The average scene luminance scale is assumed to be about 2:1 ($\log BS_o = 0.30$) at a single time and single place.

It is believed that the maximum image movement which can be permitted without perceptible loss in image quality corresponds to about 20 inches on the ground. At the altitude and speed specified this requires a maximum exposure time of not more than $\frac{1}{500}$" if there is no image motion compensation, or $\frac{1}{50}$" for

image motion compensation which is within 10% of perfect.

If film sensitivity is expressed in terms of the exposure E, in meter-candle-seconds, required to produce the minimum useful density or gradient, and minimum scene luminance B_o is expressed in foot-lamberts, the camera exposure C_E, may be computed according to the following formula

$$C_E = \frac{f^2}{t} = \frac{25 B_o}{E} \qquad (1)$$

At present it appears that FE 42090 or FE 42091 is the fastest negative material having quality adequate for this project. When this film is exposed through a #12 filter and developed fully, the value of E at the minimum useful gradient is about 0.0125 mcs. Setting this value in (1) it is seen that the camera exposure, $\frac{f^2}{t}$, must be at least f/10 at 1/100", or f/8 at $\frac{1}{150}$" for obtaining a satisfactory result with the lowest altitude sun. When the sun is at its maximum altitude the minimum luminance is 24 x that at sunrise

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or sunset. If no adjustment is made in camera exposure, the film must have a latitude of at least log 1.4 plus 0.3 for the scene range, or a total of log 1.7. Since the gamma of the negative material should be at least 2.0 for adequate reproduction of the very small luminance differences encountered in long range oblique photography, it follows that without some special controls it would be necessary to print from negatives exposed a high solar altitudes having minimum densities greater than 3.0. This means a serious loss in quality and excessively long printing times.

It is believed that the maximum useful latitude of films of high gamma ($\gamma = 2.0$) is about $\Delta \log E = 0.90$. Therefore the required scene luminance range could be accommodated with two films, one having one-eighth the speed of the other, and each having a latitude of $\Delta \log E = 0.90$.

In view of these assumptions, consider each of the camera configurations:

1. Charting camera - 70 mm format
   3" lens f/8 $\frac{1}{50}$" to $\frac{1}{300}$"
   Full image motion compensation (I.M.C.)
   Camera exposure adjusted in flight
   manually - not automatic exposure control

2. Tri-metrogon camera - 9x9 format "A-1"
   6" lens f/8 [f/18 (with mask)] $\frac{1}{125}$" or $\frac{1}{250}$"
   No IMC
   No in-flight exposure control

3 Configuration "A-2" 9x9 format
   24" lens f/8 $\frac{1}{125}$" or $\frac{1}{250}$"
   IMC good to 10%
   No in-flight exposure control

4 Configuration "B" 9x18 format
   36" lens f/10 $\frac{1}{125}$" or $\frac{1}{250}$"
   IMC good to 10%
   No in-flight exposure control

5. Configuration "C" 9x18 format
   120" lens f/16 $\frac{1}{50}$" to $\frac{1}{250}$"
   IMC good to 10%
   Automatic exposure control

The following table gives an approximate indication of the characteristics of films which might be used on this project. The values given are relative, and cannot be compared except among themselves. There are ~~four~~ five film types being considered.

Type I - Modified SO1121, low speed + 710 sens.
Type II - Higher speed version of Type I
Type III - Fine grain Recordak type
Type IV - Microfile type.
Type V - Higher speed version of Type III

These films may be coated singly or in combination and processed in various ways in order to control the speed, latitude and quality of the photographic response. In the following table, in order to simplify the presentation the maximum speed value for any particular emulsion or combination of emulsions is related to the minimum exposure capable of yielding the best quality. Lower values of speed may be associated with special processing or overexposure.

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Table I

FILM TYPE	Processing	Speed	Quality
(1) Type I	D-19 8'	100	100
" (overexposed 8X)	"	12	50
" "	Special slow developer	12	130
" "	D-19 8' + Reducer	12	50
(2) Type III	D-19 8'	12	200
(3) Type I on Type V	" "	100	100
" "	" " + Rehalogen.	8	110
(4) Type III on Type II	D-19 8'	60	80
" "	" " + Rehalogen	12	200
(5) Type IV on Type I	D-19 8'	40	100
" "	" " + Rehalogen	8	250

(1) FE-42091 Modified So-1121, low spread, 710 Sens
(2) FW-4388-3 Recordak Type "
(3) F-4538-1 Mod. SO1121 on Fast Recordak
(4) F-4533-3 Recordak on Fast SO1121
(5) F-4533-2 Microfile on Mod. SO1121

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On the basis of the data given in Table I and the lens and shutter ratings for the various camera configurations it is possible to select the best film-processing combination which might be applicable in each case:

Charting Camera.

This camera provides in-flight exposure control and full image motion compensation. It should be possible, therefore to utilize the full range of shutter times and obtain high quality results with a single film. With a maximum camera exposure of $\frac{1}{50}$" at f/8, the sensitivity, in terms of E, for the lowest level of illumination being considered is 0.04 mcs. With the minimum camera exposure of $\frac{1}{300}$" at f/8, the sensitivity, in terms of E, for the maximum level of illumination is 0.156 mcs. This suggests that the ideal film is one having about 1/3 the speed of ~~SO 1 2 1~~ FE 42691.

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Tri Metrogon Camera A-1

This camera has no in-flight exposure control, nor image motion compensation. For adequate definition the exposure times should be as short as possible, $\frac{1}{500}$" ideally. This camera has $\frac{1}{125}$" or $\frac{1}{250}$" and it is concluded that the shorter time must be used. It is believed that the anti-vignetting filter will be used with this lens and if so, the maximum effective aperture is equivalent to f/18.(?) Using the fastest film, the minimum scene luminance which will produce good negatives at this camera exposure is about 400 foot-lamberts. This indicates that the fastest film must be used (Type I) consistent with good definition, in order to obtain photographs through a useful range of daylight hours, ie, from 5° solar altitude AM to 5° PM. This, of course, means that the flights must be scheduled to avoid certain seasons of the year at the far northern latitudes. Even at the maximum solar altitude

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this camera exposure produces only about three times more the the minimum required for good quality, and is well within the latitude of the Type I film. (Aero base)

Cameras in configuration "A_2" and "B"

These cameras provide about the same range in camera exposures, both have image motion compensation and neither have in-flight exposure control. Both cameras can, therefore, offer the same problem in the selection of the best film-processing combination.

It is assumed that both cameras will be operated at maximum aperture and exposure time (equivalent to $\frac{1}{100}$" at f/10. The exposure on the film at the minimum light level is 0.0125 mcs for the darkest scene element. At the maximum light level this is about 0.3 mcs. This is much too great a range in exposures for a single film-process combination to handle. However, with the use of two

films, one having one-eighth the speed of the other (or a single film with two levels of development which produce an 8:1 speed change) this range of exposure can be successfully accommodated.

This two-step control can be worked either before, or after the film is exposed; as follows:

Two step control prior to exposure

The missions are programmed so as to be flown at such a time and at such a latitude that the light intensity varies by no more than 8 times, eg: 50 to 400 foot lamberts and 400 to 1200 foot lamberts. Use either of the following film-processing combinations.

A. Two films: Type I (fast) for the lower range and Type III (slow F.G) for the higher range

B. Single film: Use Type I film, but process fully for the lower range and process to ⅛ speed in a special slow developer for the higher range.

Two step control after the exposure

The missions are not programmed and the same film is flown, regardless of light level; the camera exposure remaining constant.

A. Interrupted processing: Type I film is used. After exposure the film is developed in a special slow developer, stopped, washed and dried. The film is read in the dark and is inspected under an infrared image converter. The negatives which have been exposed at the higher light levels will appear fully exposed; those exposed at the lower light levels will appear underexposed. The portions of the film bearing the fully exposed negatives are removed from the roll, fixed, washed, and dried. The remainder of the roll is then returned to a more active developer and processed to full density.

B. Two layer film: This film consists of two emulsion layers coated on a single film support. One emulsion has one-eighth the sensitivity of the other. Between the two is a U.V. absorbing filter layer. For maximum total sensitivity the faster emulsion is coated on top. For maximum quality, the slow emulsion is coated on top. After exposure the film is developed fully, fixed, washed and dried. The negatives may be inspected and printed at this stage. Those negatives which have been exposed to low levels of illumination will be of normal density, and no further processing is required. Those negatives exposed to higher light levels will be very dense. These negatives are removed from the roll, and the silver converted to silver halide by suitable chemical treatment. The slow emulsion is given a uniform flash exposure to ultraviolet light, which is prevented from exposing the fast emulsion by the intervening filter layer. The exposed slow emulsion is

then redeveloped and a negative image of normal density range is obtained. The silver halide of the fast layer is removed in the fixing bath.

Relative merits of the several two-step systems.

The two layer film has the following disadvantages:

1. Because the top layer absorbs some of the incident image-forming light, the effective speed of the under layer is reduced and the result is an emulsion with a low speed-graininess ratio. The fast emulsion absorbs about 80% of the light, the slow emulsion about 50%. (Effective density = 0.70 and 0.30 respectively)

2. The two layers add to the weight and thickness of the film. A 4000 feet × 9½" roll of single ~~emulsion~~ weighs about 74.5 lbs and the two ~~emulsion~~ film weighs about 87.5 lbs ~~about~~ 3420 feet of

two layer weighs the same as 4000 feet of single layer.

3. Since during most of the daylight hours the light intensity is such that a the slow film is used to record the image, most of the negatives in a two-layer system will have to be reprocessed. Any risk which may be incurred by additional handling is therefore going to affect a large number of negatives.

The interrupted process has the following disadvantages:

1. The film must be examined in total darkness before processing is complete. If the film is fogged at this point further processing will ruin the negatives.

2. The precision with which it can be determined whether further processing is required is probably not as good as it would be could the films be examined directly in white light.

The two-step pre-exposure programmed system has the following disadvantage:

1 Complex planning is required in scheduling the flights and opportunities to photograph other areas not scheduled, but accessible when the target areas are under cloud cover are largely eliminated.

The advantages of the various two-step systems are probably obvious. The best possible over-all quality (best speed-graininess ratio, etc) is with the two film pre-exposure programmed system. The two stage process, single film, pre-exposure programmed system has the advantage of simplifying the logistics problem (Only one 9½" film for the entire program). The advantage of the interrupted development system is its great flexibility in exposure with a standard film. The advantage of the two layer film system is that it achieves great flexibility in exposure while retaining best possible quality for

the greatest number of pictures.

Camera in Configuration "C"

Since ~~this camera~~ it is assumed that (will have good ~~has~~ automatic exposure control and image motion compensation which permits exposures as long as $\frac{1}{50}$" it appears that a two-step system is not required. In order to cover the light intensity range encountered Type I film is recommended. The image in this camera is ~~sufficiently large that~~ the finer grain films may not ~~offer a marked advantage~~. In any event, the slower films could not be used at the low light levels.

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Aug 18, 1955